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PROJECT MANAGEMENT TECHNIQUES FOR HIGHLY INTEGRATED PROGRAMS

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Abstract

A view of the high-technology project of the future shows a complex aircraft system that has strong interactions between elements. Simple mathematical models and diagrams are developed to show the difference between classical projects and their outcomes with a given control and how highly integrated projects react when the same classical tools are applied. This paper develops a general theoretical framework within which the dynamic process can be better understood. Specifically, the theoretical framework of modern control theory is integrated with conventional management theory to form new management approaches.

This synthesis is applied to the management and control of a representative, highly integrated high-technology project — the X-29A aircraft flight test project. The X-29A research aircraft required the development and integration of eight distinct technologies in one aircraft. The project management system developed for the X-29A flight test program focuses on the dynamic interactions and the intercommunication among components of the system. The insights gained from the new conceptual framework permitted subordination of departments to more functional units of decisionmaking, information processing, and communication networks. These processes were used to develop a project management system for the X-29A around the information flows that minimized the effects inherent in sampled-data systems and exploited the closed-loop multivariable nature of highly integrated projects.

Introduction

Changes in the business environment are considered as being evolutional by nature, yet with the rapid advance of technology — especially in electronics and computers — changes in management are almost at a revolutionary stage of development. Management theory for complex high-technology programs has not kept pace with this revolutionary development. To determine what is happening to management in high technology, look at the military aircraft industry in the past 30 years: traditionally, construction and development of an aircraft was divided into individual disciplines: aerodynamics, structures, propulsion, and controls. These areas were even further subdivided; for example, controls into interloop and outerloop. Aircraft system development projects followed the conventional management techniques of breaking the system into ever smaller parts.

There were several very sound reasons for approaching development projects in this manner. In the 1950s and 1960s, and even into the 1970s, there were sufficient advancements in each technical area so that each made significant contributions on system management. However, there was also an increasing awareness both by engineers and management that the aircraft system was not just a collection of independent components, but was a dynamic system of interrelated and interacting elements. As the complexity of the system increased, so did the complexity of the organization. When the organization was looked upon as individual departments, the approach of management was to subdivide the organization further and further. As the interactions of the departments increased, these parts were found to interrelate dynamically. Methods are just now being developed to control and compensate for these interactions that occur as a result of the nature of complex organization. As the technology of each discipline becomes more advanced, the engineer will look for integration of the technologies to produce high payoffs.

The problem of how to effectively manage a complex development project that has interrelating and interacting elements has created a need for new analysis and management techniques. The need for integration has been recognized by most major aerospace companies and government agencies, through program evaluation and review technique (PERT) and matrix management (and in a few cases, an integration manager), but neither organization has developed the theory on which to base an approach to the problem. In other words, the technical world has become more complex, but management is still using theory which was developed when the organization was structured as discrete elements.

To complicate the process further, external organizations are becoming more involved in major projects. Many future projects will be funded by multiple organizations so that the management of these projects will be a shared responsibility. This is a clear break from most past projects when management came from within the organization. Past projects did have outside influences to contend with, but such involvement has increased dramatically.

A view of the high-technology project of the future reveals a complex aircraft system that has strong interactions between its elements, both multiple inputs and outputs, and a number of real-world constraints. The development of a fixed theoretical framework that is applicable in all situations may be difficult. (See contingency theory in Ref. 1). Also, the unique environmental and human characteristics of each project need to be considered. Yet a basic general theoretical framework that would improve our understanding of the dynamic process of the interactions of project elements must be investigated.

Research Approach

The approach taken in this study was to first develop the theory to the degree needed to present a conceptual framework that can be used to view the project system and the project process. The theoretical framework of modern control systems is integrated here with classical management approaches.

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This theory is applied to the management and control of a highly integrated, high-technology project that is representative of those of the future, the X-29A aircraft project, Fig. 1.

X-29A Project Description

A major objective of the X-29A project is the "integration of multiple new technologies to obtain significant synergistic capabilities." The project has a complex management structure because there are seven organizations participating in the project: the Defense Advanced Research Project Agency (DARPA) the National Aeronautics and Space Administration (NASA), Grumman Aerospace Corporation (GAC), the Air Force Flight Dynamics Laboratory (AFFDL), the Air Force Flight Test Center (AFFTC), the Navy, and Calspan. All organizations have either a formal contract or memoranda of agreement which defines their various roles.

The theory developed in this study is applied with respect to the role of NASA, which is responsible for providing technical advice and support and to perform an independent evaluation of the various technologies as well as flight testing the X-29A. Ten functional organization groups within NASA perform the actual project work. The operational interrelation and interactions of these groups are similar, yet on a managable scale, to the total operation of the X-29A project.

Analysis of Management Systems

Before proceeding in the definition of the X-29A Project Management System, a discussion on socio-economic models is required. Pindyck[2] has pointed out "Our preoccupation with linear time-invariant systems is not a reflection of a belief in a linear time-invariant real world, but instead a reflection of the present state of the art of describing the real world." Project Management's preoccupation with discrete-time models follows the same reasoning because of the periodic accumulation of data that describes the state of a system.

Sampled-Data Systems

Because the operation of a real-world project is a continuous process, it would be more accurately described by a continuous-time model. However, project management has taken what is essentially a continuous real-world process and converted it into a sampled-data system by developing a management process that samples status or technical data periodically in the form of weekly reports, monthly design reviews, design freezes, or the like. Management compares the status information with desired outputs and makes corrections to the project based on this data. Both the data and the control policies are held until new data are obtained. Because the status data are gathered on a periodic basis, any control policy is consequently made on a periodic basis, using the gathered data. This type of process is termed a "sampled-data" system. The status information and the resulting management decisions are generally held up until the next reporting period. These periods are artificially controlled by management, but in real-world projects, there are practical limits. Nevertheless, understanding what occurs when one samples a continuous process and what dynamic effects occur when one holds that information is of great importance to management systems.

What effect does this sampled-data approach have on the process? The information theory has shown there are lower limits to how often one needs to sample a system. If continuous-type information is changing rapidly with time, then sampling the signal at too low a rate may miss vital information present between sampling instants. Consequently, it may not be possible to reconstruct the original information from that contained in the sampled data. From a mathematical point of view, this has been proved by Shannon[3] and reported in many texts.[4] Therefore, project management must continuously trade-off the higher sample rate cost with the loss of information from the lower sample rate.

In project management systems, the status information is not just sampled at a discrete time interval, but is held until the next reporting point. Management decisions to control the project made by using this information are also held until new information is obtained. The holding of information and decisions can be modeled very accurately. This is illustrated in Refs. 4 and 5, and is illustrated in Fig. 2. This holding process becomes very important in understanding its effect on dynamic feedback systems and is termed "sample-and-hold."

If two processes are performed independently, the block diagram would be as shown in Fig. 3. This process is termed a parallel continuous-time process. If they are performed in series with the second using the output of the first, as shown in Fig. 4, the process is termed an "open-loop series" process.

If the output of the first process is used as the input of the second, and if the output of the second is used to determine if the original requirements have been met, then the block diagram is as shown in Fig. 5. This process is termed a "closed-loop" process. The real-world project management system is of this form and is a closed-loop process. A closed-loop process in which functional groups interact is shown in Fig. 6. For example, think of process 1 as the aerodynamic design, and of process 2 as the design of an aircraft control system. In past years when aircraft systems were less complex, the aerodynamic design and the control-system design could proceed almost in parallel because they were virtually independent activities; as the complexity of aircraft systems increased, the two activities became more interactive and a closed-loop relationship between the activities developed. In the future of the real-world of aircraft design, the basic aerodynamics will have to be supplemented with the control system. That is, the aerodynamics must be developed first, and then the control system must be designed. The complete system is then checked to determine if system requirements are met. If not, changes will be made in the aerodynamic design, in the control system design, or in both.

Although only two loops are discussed here, there are multiple loops in a complex aircraft system, such as structural dynamics and aerodynamics, structural dynamics and control-system dynamics, and aerodynamics and control-system dynamics. All of these interactions occur simultaneously and can be described using the state-variable representation of modern control theory (described in Refs. 5 - 7).

As discussed earlier, the basic technical data and status information are transmitted to management on some periodic basis. A representation of a typical sampled-data system is shown in Fig. 7. In Fig. 7, the sampling operation is applied to the error signal. Frequently in project management systems, it is necessary to sample the feedback, or error signal. The hold block is usually just a zero-order hold in which the information is kept constant until the next information is obtained. An example of a zero-order hold operation in project management is a design freeze that will not be changed until some future time. Generally, the progress status of an aircraft system is measured and fed back to management or updated on a periodic basis such as daily, weekly, or monthly. When certain signals in a conventional closed-loop feedback system are used at discrete times, such a system may be viewed as a sampled-data system for which detailed mathematical development can be found in Refs. 4, 5, and 8.

To illustrate a sampled-data closed-loop system, consider a project that consists of two processes with tasks such as gathering aerodynamic data on a continuous basis and designing a control system on a continuous basis. Simple linear deterministic models are used for this example to show the process.

The two processes described by the input-output block diagrams are illustrated in Fig. 8. The processes are described in terms of their Laplace transforms, which are defined in Refs. 4 and 5.

In this example these two simple processes are to be done in series, and the output is then to be fed back to determine if it meets the performance requirements. To evaluate and understand the effect of sample-rate on a sample-data system, a comparison can be made between the performance of a continuous project model and a real-world product where it is sampled at discrete intervals as shown in Fig. 9. Reference 5 shows that if the data are sampled once a day, the process will be completed in about the same time as if it were continuous (4 weeks). On the other hand, if a sample is taken as infrequently as every week or every second week, the time for completion is extended to 12 and 24 weeks, respectively. In these cases, the performance requirements would be met, but when the sample rate is increased to every 4 weeks, the project system becomes unstable and never reaches a satisfactory completion.

Therefore, a process for which a satisfactory answer would be obtained in about 4 weeks (if there was a daily information flow) will never obtain a satisfactory answer when information is fed back monthly. This destabilizing effect that occurs because of the sample-and-hold process is not usually considered by management when processing either technical information or management information.

Although the above example is not designed to represent an exact project management model, and although the time frame may not be representative of a real project, it serves to demonstrate the effects of sampling on systems. Larger, more complex models could be developed that would be more representative of a project, but the effects of a sample-and-hold system would be similar. (Detailed mathematical development of sampling can be found in Ref. 5). This information should alert the manager that the selection of the sample rate of a management system or of technical information is no arbitrary matter and should be based on a number of factors seldom considered; for example, the frequency content of the information to be processed, dynamics of the process, and the nature or structure of the interactions of the process.

Delay

The normal project system might comprise such activities as developing control laws, writing software specifications, developing, verifying, and validating software. As each activity is completed, the product of that activity is passed to another functional group to initiate the next activity. This transfer of information is in the form of documentation such as specifications, test reports, and interdepartmental correspondence, or other completed work. Each transfer of information produces a delay in the project. Additionally, each layer of personnel, either vertical or horizontal, produces a built-in delay in the system. Management has always tried to reduce this because it was recognized that it would compound delays in the project completion. In a simple, open-loop system the delays are additive, so the total delay is the sum of all the system delays.

However, when feedback exists (creating a closed-loop system) the effect of the delay is complex but, in general, tends to be destabilizing to the project. The total length of the project tends to become extended by more than just the length of the basic delay. The mere addition of a delay can produce an instability in a closed-loop system. Although in the theoretical world it would seem that this would mean a project might never meet its objective, in the real world the project system would adapt to the delays, but the time to complete the project might be excessive.

Most project managers try to reduce delays because they see them as increasing the cost and the length of time it takes to complete a project. However, they generally do not consider the destabilizing effect that occurs as a result of the delay. When elimination of delays involve costs, most managers would not spend the extra effort if not required to meet schedules. Yet the effect of such delays on a closed-loop system can be much greater than the open-loop delay.

In many cases the delays are actually added to the system in what would normally be considered good project management. A reporting point or deliverable item would be documented and formally reported and transmitted to the other functional group for use in the next task. The delay would be considered part of the cost, in terms of time and money, of transmitting the data. Many times delays are added to the information flow in the form of moving data from department to department or from division to division; thus the structure of the organization can build the delays into the project system.

Control-system theory shows that the cost of these delays in a closed-loop system can be much greater than would be expected by an open-loop analysis. Management needs to be aware of this when developing systems that contain feedback loops. Also, managers need to evaluate the closed-loop nature of the project to determine what delays exist and then to structure the information flow so that the delays will be reduced as far as practical.

Since it has been shown that both the sample-and-hold process and the delays tend to be destabilizing to a closed-loop system, many times there can be trade-offs made between two processes. But management needs to recognize that neither is a solution for the other and that either can produce poor performance.

X-29A Project Management System Description

The theory and concepts that have been developed in the previous sections using systems theory, modern digital control theory, and information theory are integrated with conventional management tools to form the project management system for the X-29A flight test project. This project management system has provided a framework for planning, statusing, and controlling the project with a clear understanding of the operation of the project. The basic structure of the system was developed through discussions with John A. Dietrich and Associates, a project management consulting group. The system is comprised of four basic steps designed to produce the appropriate information for effective project management.

Project Objectives and Requirements

The first step is to produce a project plan that provides an overview of the total project. This project plan contains the background, overall objective, project scope, technical approach, test requirements, and management reporting requirements. All of these items are described in general terms. This document must be approved by all organizations involved and provides the basis for directing the entire project.

Also, there is a need to state the project's objectives to determine how they can best be met. The overall project objective must be broken down into a subset of specific objectives which are concise and tangible. These specific subobjectives become the targets of the project and are the basis for measuring performance. A document defining and specifying detailed requirements for each specific objective must be produced. These documents are the basis on which all project technical decisions are made. Consequently, approval of the various managing organizations is required. In the X-29A Project Management System, each subobjective is analogous to an output of a theoretical control system.

From a theoretical standpoint, the critical element is the establishment of the desired outputs of the project, which in this case are the specific objectives of the project. Each objective must be both quantifiable and measurable because the project's process in attaining objectives will provide status information that is measured and compared with the ideal values. This process is similar to any management system that uses a management-by-objectives approach, except in this case it is part of an overall project management process that can best be seen as a modern control system (Fig.10) in which the desired states are compared with the actual states and any error is fed back, along with the desired control. A more conventional look at the project planning process is shown in Fig. 11. This process points out the closed-loop nature of the system. Only one loop would normally be shown in the figure. The dashed feedback lines are drawn to show the multiple-loop nature of the process.

Information Processes

The systems information and control theory begin to play a critical role in the next step of the X-29A Project Management System. Historically, project management would structure the information process based on the functional organization. System theory and modern control theory focuses on the interrelationships and the dynamic interactions that take place when information is processed in the operation of the project. When determining the information process needed to meet the specific objectives of the project, the organization's functional structure must be disregarded. Management must look upon the project as an information network. Therefore, when this technique is used, information flow can be developed to meet the objectives and provide management with data needed for control. It is no longer appropriate to look only at physical tasks, but instead we must consider an information processing network.

Consequently, the second step in the X-29A Project Management System is the identification of an information process and the production of an appropriate block diagram. The development of a project information process needs to be a group effort including the individuals who are responsible for accomplishing the various activities, the individuals responsible for integrating all of the work (the project engineer), and the planning personnel who are responsible for the planning tools. A typical information process block diagram is shown in Fig. 12. Information that is needed from other people, groups, or organizations should be shown on the diagram along with the process and the products of the work. These inputs from other systems can be looked upon as states of a larger system that includes the dynamics of each system involved. In this way, the interactions with the other systems and the external environment can be seen better. Also, the practicality of controlling the total system can be evaluated.

These information process block diagrams are used to determine where and if feedback is part of the process where the system is continuous, and where sampling is used. Status information sampling rates are established that are high enough to meet the system's requirements. It can also be determined where delays exist in the process, and whether the process can be streamlined to reduce these delays, particularly when they occur in a feedback loop. These information networks may or may not resemble the functional organization. When using the X-29A Project Management System, development of the information processing diagram must take place, regardless of the structure of the organization.

In general, as the information is processed from block to block, each block tends to lag the information as part of its transformation between blocks. These pure delays tend to occur with no transformation of information. In general, if the blocks are in different organizations, or if the organizations are far removed from one another, the delays are longer. These delays are generally the result of both physical variables and organizational behavior-type problems. As discussed in an earlier section where information processes are necessary in a closed-loop system, it is critical to reduce these delays.

The following exemplifies this concept. One of the closed-loop processes on the X-29A project is NASA's analysis of the X-29A control laws. Inputs come from the control law design and the aerodynamic models. The process involves control system, aerodynamic, and simulation personnel. The output of the analysis is compared with desired results and feedback is used to redesign the control laws. Initially, an information process was established that reflected the conventional approach. The input information came from GAC on a periodic basis in the form of formal documents. The documents then flowed from the GAC, through the AFFDL, to the NASA project office. The aerodynamics document was then sent to the aerodynamics functional group, and the control law document was sent to the control system group. Both groups conducted a review of the documents and then sent the reviewed information to the simulation group for implementation. After implementation of the simulation, the control law data were analyzed. The results of the analysis were then sent from the control system group to the X-29A project office, to AFFDL, and then forwarded to GAC.

On paper, this process would appear to have the situation well controlled. However, the control design, control analysis, control redesign, and control re-analysis is a closed-loop system. As stated earlier, delay can destabilize a closed-loop system to the extent that the system becomes unstable. Therefore, new information paths have been developed to shorten the delays. Technical data now flows at a higher rate directly from GAC to NASA whenever possible. Within NASA, the information goes directly to the simulation group where it is processed. Control law documents go directly to the control system group where a working relationship has been established with the simulation personnel that minimizes the delay in implementation. The aerodymamics documents go to the control system group where, because of the close interaction with the simulation group, they are immediately processed. In addition, a copy of the document is also sent to the aerodynamics group for processing. The analysis results are sent directly to GAC. Meanwhile, the slower-rate data is sent to the NASA project office, via GAC and AFFTC, to allow tracking of the tasks and to ensure proper timing. This new process has been so effective that on occasion, the new control law implementation and preliminary analysis process has been completed before the arrival of the data through the formal process that still includes all the delays and the slower update rates.

When the control system analysis activities were determined to be part of a feedback loop, every effort was made to implement the physical information process in such a manner as to reduce the delays in the process. Although it is typical for any project manager to try to simplify any repeated process reducing delays becomes even more important because of the closed-loop requirements and the resulting instabilities. For the above X-29A control system analysis, the need to minimize the lags of the analysis was recognized. Extra time was spent before the arrival of the control laws to design a process that would reduce the time required for analysis.

Roles and Relationships

In defining roles and relationships, many organizations do little more than publish organizational charts and position descriptions. The conventional organizational chart does show the basic division of work and who reports to whom, but it does not illustrate detailed functions and how individuals relate to these functions. It does not show how the project organization really operates. The objective of position descriptions is to define what an individual's tasks are, rather than how he interacts with his colleagues in carrying out his responsibilities.

The third step in the X-29A Project Management System is to define the roles and relationships of the various project personnel. To do this, a standard-looking block diagram is used to illustrate who does what for the project (an example for the control law analysis process is shown in Fig. 13). With this type of diagram it is possible to determine which tasks are to be accomplished and by whom, and also with whom that individual must interact to accomplish the work. A fallout of this step is an improved understanding by the various project personnel as to how they fit in the overall operation of the project. It gives each member of the project a view of the interaction that must take place in order for the group to function effectively. Moreover, management has an opportunity to view how the project operates, how the personnel relate to one another, and how management relates to them. The diagram is basically another way of showing information flow, but it provides the advantage of crossing organizational lines and assigning responsibilities to the person who actually performs the work. This information will be used later when producing the work breakdown structure; it will show working interfaces that would not appear on organizational charts.

The process of developing the roles and relationship diagrams is very valuable to management. The information gained from discussions with the project personnel was invaluable for the person performing the integration role on the X-29A. It showed which relationships existed and which ones needed to be developed. Roles that had been ill-defined or unknown were identified by the process. In one case a new group was formed to ensure a direct responsibility of a required task. In other cases relationships were developed via the integration manager. These were done on an individual basis in response to the need that was determined for the roles and relationship analysis.

Planning for Control

The fourth step in the X-29A Project Management System is the development of a work breakdown structure (WBS). The techniques described herein are WBS methods and critical path methods (CPM), which are not new, yet the application combined with the control theory is significant to management because it allows better control of the project. Many managers have used PERT or CPM for control, but it has not been truly effective. One reason for this has been a lack of understanding of the control process and the system dynamics.

How the WBS is developed by the work group is as important to its successful completion as what elements it includes. The tasks should be broken down to the level that is best for tracking and controlling the project. Each element must be agreed to by all involved personnel. An example of one level of WBS for the X-29A flight test project is shown in Fig. 14. A general example of how the WBS fits together to form the integrated schedule can be seen on Fig. 15. An important part of the process is the development of the WBS to a level that can be measured and that is representative of the status of the dynamic system. On the X-29A project this was accomplished by working with many people: the project management, the team leaders from the functional groups, the various individual working level personnel, and the personnel from the planning group. It is important to recognize that the WBS information must be useful for tracking and controlling, resulting in the accomplishment of the specific objectives of the project.

From the WBS, a schedule is developed through a process of repeated negotiations between project manager and project personnel. For a complex, high-technology project such as the X-29A project, the resulting schedule is highly integrated; that is, many of the WBS elements are interrelated. This, again, confirms the fact that the X-29A project is a closed-loop system with multiple loops.

A project management software package (TOPMAN), described in Ref. 9, was used on the X-29A project. It allowed the development of an integrated schedule and resource plan that is used not only to inform management of the status of the project, but also to allow the optimal control of the project system. With an automated tool such as TOPMAN, it is possible to monitor the status of the project system and control the schedule and resource expenditure. Moreover, the actual performance of the project can be measured.

This process, as applied to the X-29A project, required that more information be fed back to management. The need for understanding sampling theory and how this affects the process of closed-loop systems has been discussed in this paper. In the literature of the project management software package, TOPMAN, the importance of frequent updating of the project management system is discussed as follows: "During the maintenance phase, the project data base must be updated as frequently as necessary to keep the project manager fully informed of the status of the project. If this is not done, a dynamic or complex project can quickly get out of control, and once out of control, the impact in terms of time and expenditure may well lead to disaster." This is the essence of the discussion on the sampling rate, yet as has been shown, it is also critical to the completion time and the stability of the closed-loop system. If the standard formal reporting process is used, the cost in terms of manpower can be great, but NASA used many less time-consuming methods to gather and update the data as needed. The system information that was needed for control was determined early and a sample rate was selected to ensure control of the project.

Concluding Remarks

The method used by the X-29A project to plan and control the project provides management and other personnel with a clear understanding of the project's objectives and operation. The first step of the process is to clearly define the project objectives and requirements. The second step is to identify the information process that would provide effective and timely flow of both management and technical information. An important element of this step is the identification of feedback loop within the project so that information transformation delays can be reduced as much as possible. To accomplish this, it is often necessary to examine the operation of the project at lower levels than is customary. The third step in the X-29A Project Management System is to clarify the roles and relationships of the various individuals participating in the project. Finally, an integrated schedule and resource plan that is based on an encompassing work breakdown structure is created. The WBS is developed to a level that is sufficient to effectively control the project and to allow the project to completely meet its objectives.

In order to effectively use the X-29A Project Management System, it is necessary to understand that a project system is a closed-loop control system with feedback loops and is affected by data sampling-rate and information delays. In the past, the system dynamics were not considered when determining at what level the progress of the project system should be tracked. The result was significantly overextended and overexpended projects. Tailoring the project system for implementation and control to the particular operation of the project can significantly improve project performance. The X-29A Project Management System approach allows the manager to match his planning and control system to the process to be controlled.

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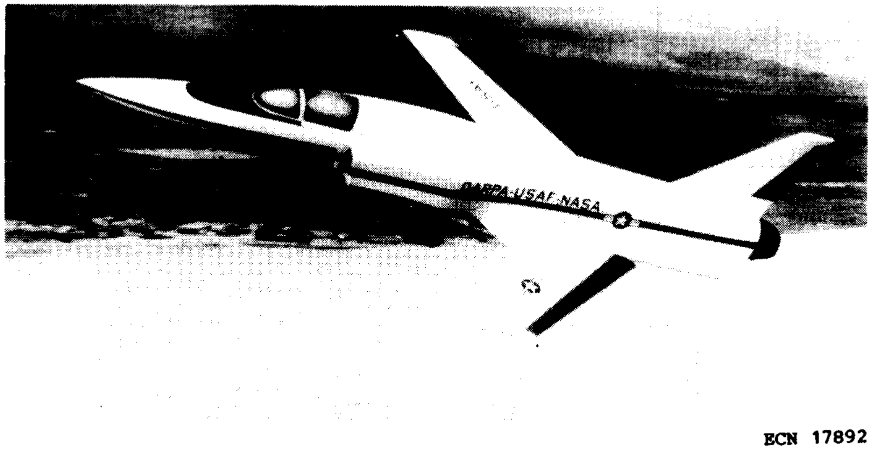

Fig. 1 X-29 advanced technology demonstrator.

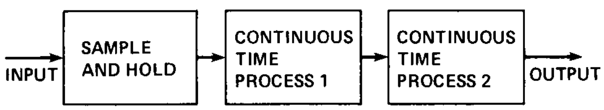

Fig. 2 Sampled data system.

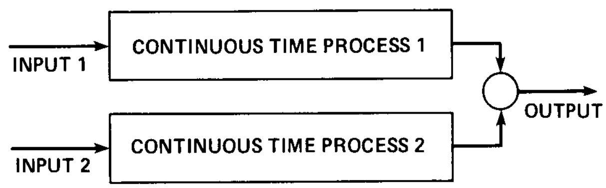

Fig. 3 Parallel continuous time processes.

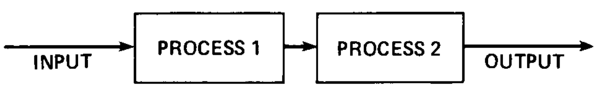

Fig. 4 Open loop series process.

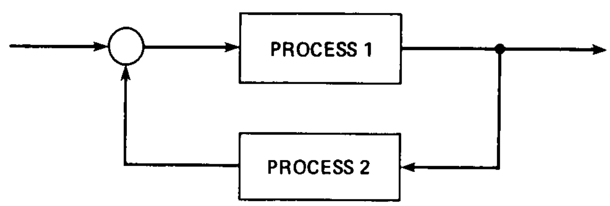

Fig. 5 Classical closed-loop system.

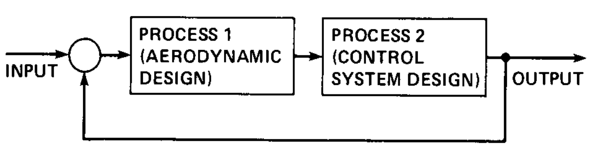

Fig. 6 Closed-loop system configuration.

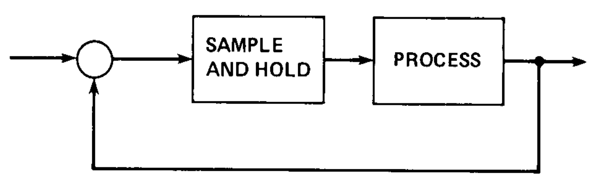

Fig. 7 Closed-loop sampled-data system.

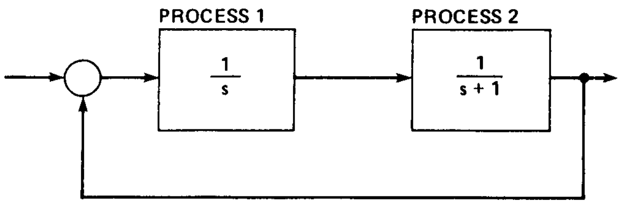

Fig. 8 Continuous closed-loop system.

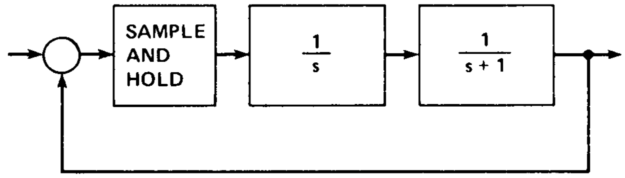

Fig. 9 Sampled-data closed loop system.

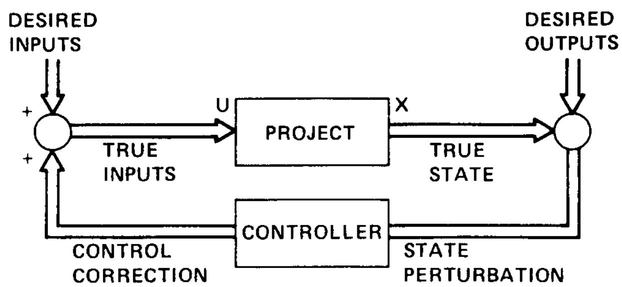

Fig. 10 Structure of optimal feedback control system.

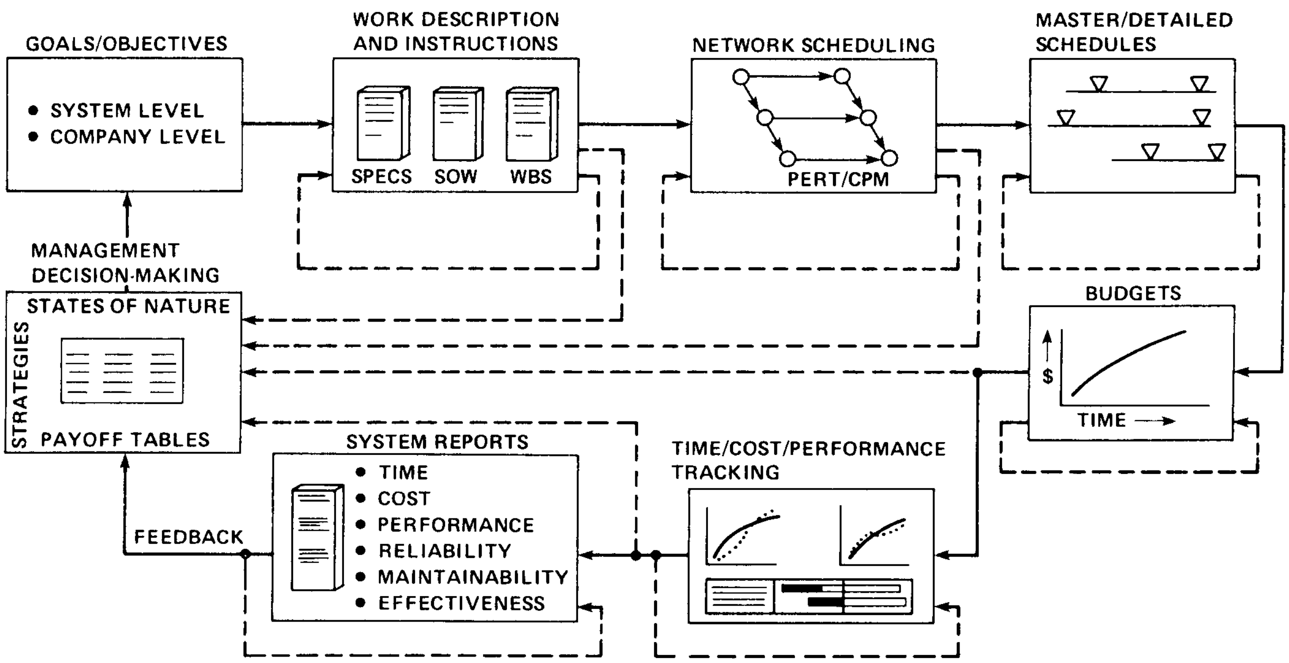

Fig. 11 Project planning and control system.

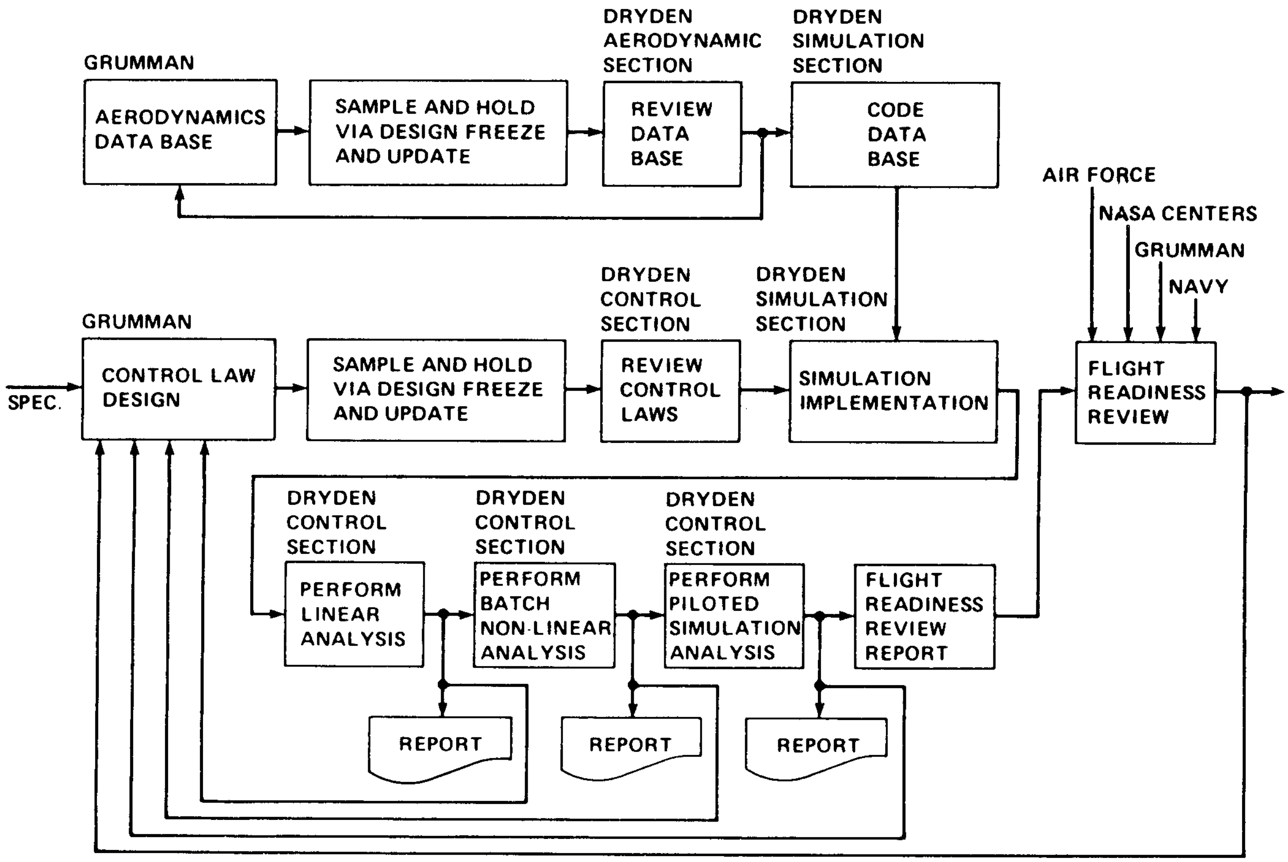

Fig. 12 Information flow diagram.

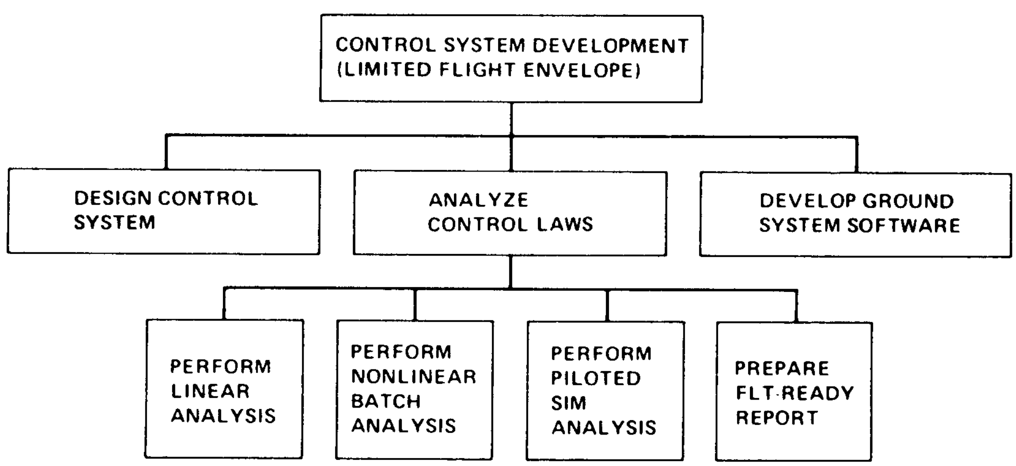

Fig. 13 Work-breakdown structure for control system analysis.

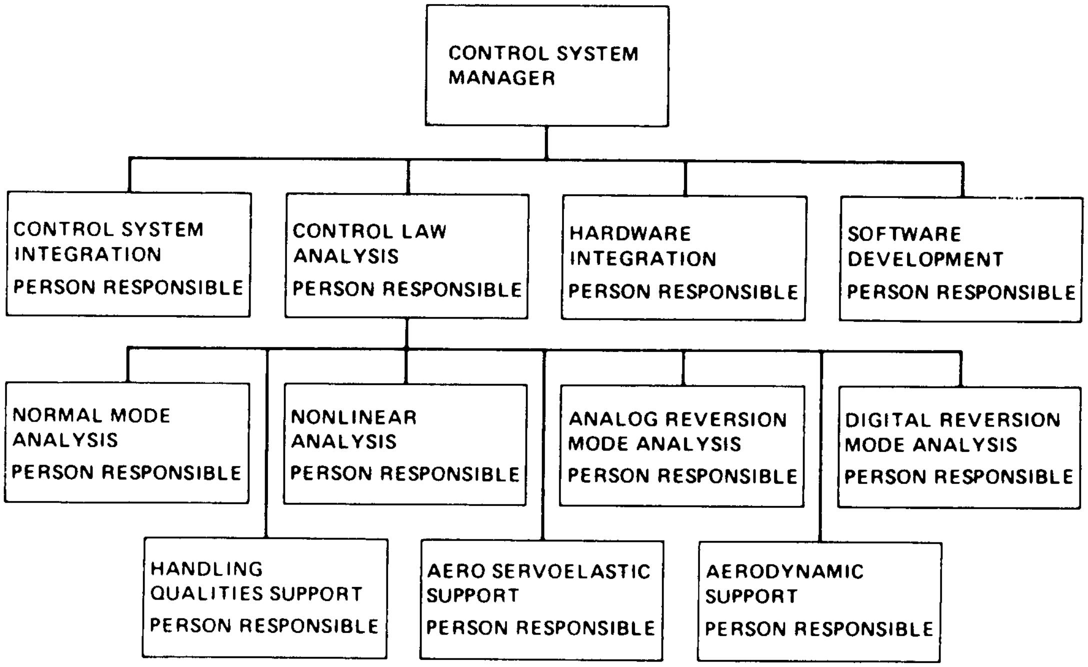

Fig. 14 Roles and relationships diagram.

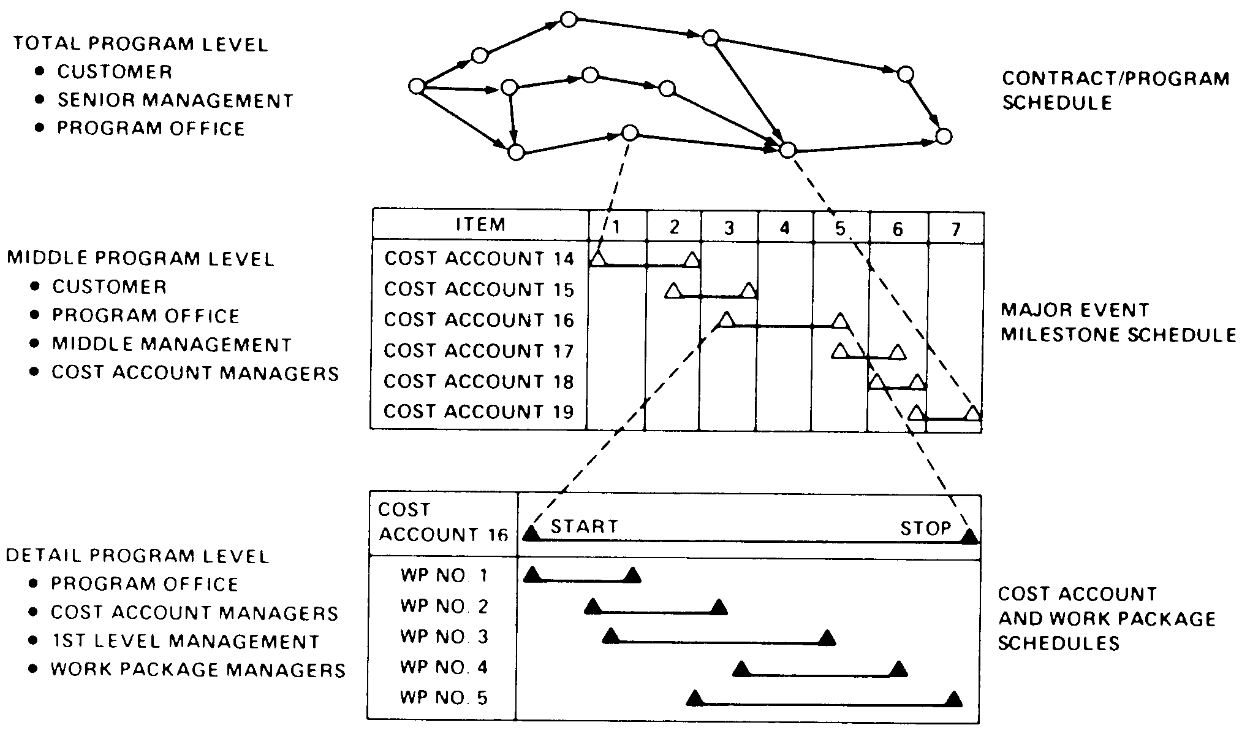

Fig. 15 Schedule integration.

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16. Abstract

A view of the high-technology project of the future shows a complex aircraft system that has strong interactions between elements. Simple mathematical models and diagrams are developed to show the difference between classical projects and their outcomes with a given control and how highly integrated projects react when the same classical tools are applied. This paper develops a general theoretical framework within which the dynamic process can be better understood. Specifically, the theoretical framework of modern control theory is integrated with conventional management theory to form new management approaches.

This synthesis is applied to the management and control of a representative, highly integrated high-technology project - the X-29A aircraft flight test project. The X-29A research aircraft required the development and integration of eight distinct technologies in one aircraft. The project management system developed for the X-29A flight test program focuses on the dynamic interactions and the intercommunication among components of the system. The insights gained from the new conceptual framework permitted subordination of departments to more functional units of decisionmaking, information processing, and communication networks. These processes were used to develop a project management system for the X-29A around the information flows that minimized the effects inherent in sampled-data systems and exploited the closed-loop multivariable nature of highly integrated projects.

17. Key Words (Suggested by Author(s))
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